On binary pulsars and the force of gravity

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We reanalyze a binary pulsar system and show that the orbital period change rate can be completely understood as a curvature backreaction process. Appreciating a detailed theoretical and observational study of relativistic binary pulsar systems, especially the system of Hulse and Taylor, we conclude that general relativity and astrophysical observations rule out the existence of gravitational radiation. Thus, the force of gravity is not a local gauge force.

The discovery of the binary pulsar B1913+16 by Hulse and Taylor [1] represents a milestone in astrophysics because relativistic binary pulsar systems are perfect laboratories to study general relativity. In the past decades very detailed calculations were performed in the post-Newtonian approximation with all possible relativity corrections to measurables (see, for example, [2], [3], [4] and references therein).

However, it seems that one important part of calculations is not included into the analysis of a relativistic binary system. Namely, the impact of the spacetime curvature on the observables of a binary bound system is not elucidated in all respects.

Let us define a metric in the following form:

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}.$$

It is suitable for the treatment of an isolated bound system if we assume that $h_{\mu\nu}$ vanishes at infinity. One can now write Einstein equations in the following form (see $$ 7.6 of the book in [5]; we accept conventions of this book):

$$R^{(1)}_{\mu\nu} - \frac{1}{2}\eta_{\mu\nu}R^{(1)\lambda}_{\lambda} = -8\pi G_N[T_{\mu\nu} + t_{\mu\nu}],$$

$$R^{(1)}_{\mu\nu} \equiv \frac{1}{2}(\frac{\partial^2 h^{\lambda}_{\lambda}}{\partial x^{\mu}\partial x^{\nu}} - \frac{\partial^2 h^{\lambda}_{\mu}}{\partial x^{\lambda}\partial x^{\nu}} - \frac{\partial^2 h^{\lambda}_{\nu}}{\partial x^{\lambda}\partial x^{\mu}} + \frac{\partial^2 h_{\mu\nu}}{\partial x^{\lambda}\partial x_{\lambda}}),$$

$$t_{\mu\nu} \equiv \frac{1}{8\pi G_N}[R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R^{\lambda}_{\lambda} - R^{(1)}_{\mu\nu} + \frac{1}{2}\eta_{\mu\nu}R^{(1)\lambda}_{\lambda}],$$

$$\tau^{\nu\lambda} \equiv \eta^{\nu\mu}\eta^{\lambda\kappa}[T_{\mu\kappa} + t_{\mu\kappa}],$$

$$T_{\mu\nu} = energy - momentum\ tensor\ of\ matter.$$

Note that the new energy-momentum "tensor" $\tau^{\nu\lambda}$ is a locally conserved quantity [5]:

$$\frac{\partial}{\partial x^{\nu}}\tau^{\nu\lambda} = 0.$$

This is also valid for the angular momentum

$$\frac{\partial}{\partial x^{\mu}}M^{\mu\nu\lambda} = 0,$$

$$M^{\mu\nu\lambda} \equiv \tau^{\mu\lambda}x^{\nu} - \tau^{\mu\nu}x^{\lambda}.$$

One should also remember that the "gravitational energy-momentum tensor" $t_{\mu\nu}$ is quadratic in $h_{\mu\nu}$ and its derivatives [5].

Without loss of generality, we choose a harmonic coordinate system

$$g^{\mu\nu}\Gamma^{\lambda}_{\mu\nu} = 0,$$

and express gravitational potentials through sources in the linear approximation ($T_{\mu\nu}$ to lowest order in $h_{\mu\nu}$) [5]

$$h_{\mu\nu}(\vec{x},t) = 4G_N \int d^3\vec{x'} \frac{S_{\mu\nu}(\vec{x'}, t- \mid \vec{x} - \vec{x'} \mid)}{\mid \vec{x} - \vec{x'} \mid},$$

$$S_{\mu\nu} \equiv T_{\mu\nu} - \frac{1}{2}\eta_{\mu\nu}T^{\lambda}_{\lambda}.$$

This was done by Einstein [6] and Pauli [7], and also rederived by Synge [8]. However, it was shown that Einstein field equations could be cast in the form of integral equations for metric, so the above relation is just a linear approximation of more general equations [9].

From the locally conserved "energy-momentum tensor" we can evaluate the energy loss of the relativistic binary system [5, 10]

$$\frac{dE}{dt} = -\frac{G_N}{5}[\frac{d^3Q_{ij}}{dt^3}\frac{d^3Q_{ij}}{dt^3} - \frac{1}{3}\frac{d^3Q_{ii}}{dt^3}\frac{d^3Q_{jj}}{dt^3}],$$

$$Q_{ij} = \sum_a m_a x^i_a x^j_a = mass\ tensor,\ i,j = 1,2,3$$
$$(similarly\ for\ the\ angular\ momentum).$$

The orbital period change rate due to the "curvature backreaction" is then, by definition, after averaging over one period of the motion [2, 10, 11]:

$$\dot{P}_b = f(P_b, e, m_p, m_c),$$

$$\begin{aligned} f(P_b, e, m_p, m_c) &= -\frac{192\pi G_N^{5/3}}{5}(\frac{P_b}{2\pi})^{-5/3}(1-e^2)^{-7/2} \\ &\quad \times(1 + \frac{73}{24}e^2 + \frac{37}{96}e^4)m_p m_c(m_p + m_c)^{-1/3}, \end{aligned}$$

$$e = eccentricity,\ m_{p;c} = mass\ of\ the\ pulsar; companion.$$

First of all, one should notice that the contribution of the curvature back-reaction to $\dot{P}_b$ is the same as that of gravitational radiation. This is not a surprise because they are generated by the same source field, derived within the same linear approximation and the same assumptions on the behaviour of fields and their derivatives at infinity, except that gravitational potentials should fulfil harmonic coordinate conditions, while the tensor field should fulfil harmonic gauge conditions.

Let us inspect the energy budget of the process. The total energy and angular momentum conservation follow from the general relativity conservation equations

$$\nabla^\mu T_{\mu\nu} = 0,$$

$$\nabla_\nu V_\lambda \equiv \frac{\partial V_\lambda}{\partial x^\nu} - \Gamma^\kappa_{\lambda\nu} V_\kappa.$$

Namely, the "energy-momentum tensor" $\tau_{\mu\nu}$ does not contain a gravitational part that is linear in $h_{\mu\nu}$. Thus, the kinetic energy loss of $\tau_{\mu\nu}$, which is due to the nonvanishing orbital period change rate, is compensated by the potential energy gains hidden in $h_{\mu\nu}$:

$$\Delta E(kin.\ en., \dot{P}_b \neq 0) + \Delta E(pot.\ en.\ change\ in\ h_{\mu\nu}) = 0.$$

In the case of gravitational radiation, the kinetic energy loss in $\dot{P}_b$ is compensated by the energy deposited in the emitted tensor field:

$$\Delta E(kin.\ en., \dot{P}_b \neq 0) + \Delta E(en.\ deposited\ in\ grav.\ waves) = 0.$$

Acknowledging the preceding discussion, we can conclude

$$gen.\ rel.:\ \dot{P}_b = f(P_b, e, m_p, m_c),$$

$$gen.\ rel.\ +\ grav.\ rad.:\ \dot{P}_b = 2f(P_b, e, m_p, m_c).$$

Very precise measurements of the binary pulsar B1913+16 with an overdetermined set of measurables give [12]

$$\dot{P}_b(gen.\ rel.) = f(P_b, e, m_p, m_c) = (-2.40247 \pm 0.00002) \times 10^{-12},$$

$$\dot{P}_b(measured) = (-2.4086 \pm 0.0052) \times 10^{-12}.$$

Thus, general relativity and binary pulsar measurements completely rule out the existence of gravitational radiation with very high statistical confidence. Of course, neglect of the curvature backreaction process leads to a wrong conclusion on the existence of the tensor gauge force.

It is very difficult to comprehend that the force of gravity could be described as a long-distance "global" force in the Newton-Einstein sense and at the same time as a short-distance local gauge force like electroweak and strong interactions. The present discussion resolves this dilemma uniquely and with no doubts.

One can ask about a unification programme starting from the early Einstein attempts [13] to the contemporary research (as well as the search for "quantum gravity"). The importance to study the Einstein-Cartan (quantum) cosmology is to remove mathematical inconsistencies of Einstein's theory of gravity and to solve cosmological problems without the inflationary scalar field [14]. It is necessary to have a link between gravity theory and elementary particle physics with noncontractible space as a symmetry breaking mechanism without Higgs scalars, no asymptotic freedom in QCD and with light and heavy Majorana neutrinos as hot and cold dark matter particles [15].

The result from the binary pulsar should not discourage a search for gravitational radiation because the confirmation of the negative result should be of fundamental importance just like the negative result for the ether drift in the experiment of Michelson and Morley.

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